Original article

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Children with benign epilepsy with centrotemporal spikes (BECTS) show impaired attentional control: evidence from an attentional capture paradigm

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ABSTRACT – Children with epilepsy often have attention deficits, even when epilepsy is idiopathic and benign. The mechanisms underlying attention deficits are still unknown and appear to be different between focal and generalized epilepsy. In this study, an attentional capture paradigm was used to study and compare one aspect of attentional control, the resistance to interference from distractors, in 18 children with benign epilepsy with centrotemporal spikes (BECTS), 18 children with idiopathic generalized epilepsy and 18 controls aged 7-12 years. The results showed longer response times (RT) and more omissions in the two groups with epilepsy compared to controls. Attentional capture with longer response times in trials with a moving distractor compared to baseline condition with stationary distractors was found in both controls and children with epilepsy. The magnitude of interference from moving distractors was greater in the BECTS group than in the idiopathic generalized epilepsy group and in the controls group. These results suggest an impact of epilepsy on resistance to interference from distractors in children with BECTS.

Key words: childhood epilepsy, distraction, interference, inhibition, rolandic epilepsy, idiopathic epilepsy, BECTS

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Benign childhood epilepsy with centrotemporal spikes (BECTS) is the most frequent type of epilepsy in children. According to the International Classification of Epilepsies and Epileptic Syndromes (Commission on classification and terminology of the ILAE 1989), BECTS is age-related (occurring between 3 and 13 years, in children with normal psychomotor deve-

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lopment) and is considered to be a benign epilepsy syndrome because seizures are usually easily controlled by antiepileptic medications and disappear in adolescence. However, the prevalence of learning difficulties and clinical neuropsychological studies indicate that the cognitive prognosis is not as favorable (De Saint-Martin *et al.* 2001, Pinton *et al.* 2006).

Most studies that have evaluated children with idiopathic epilepsy using standardized tests or behavioral questionnaires completed by the parents, suggest executive and attentional impairments as well as slowing of information processing in these children [with idiopathic generalized epilepsy (IGE): Henkin *et al.* 2005; with focal idiopathic epilepsy including BECTS: D'Alessandro *et al.* 1990, Weglage *et al.* 1997, Croona *et al.* 1999, Metz-Lutz *et al.* 1999, Pinton *et al.* 2006].

In studies concerning childhood epilepsy, experimental tasks have rarely been used to define the attentional and executive processes affected. To date, only prepotent response inhibition, one specific aspect of attentional control, has been studied in children with epilepsy. Published results suggest difficulties of inhibitory control in children with focal idiopathic epilepsy (Chevalier *et al.* 2000, Gündüz *et al.* 1999). The ability to resist interference from distracting signals represents another aspect of control that is critical for coherent behavior (Milliken & Tipper 1998, Yantis 1998, LaBerge 1999). This ability is particularly important for the control of exogenous orienting, as, if attention is captured by any signal occurring in the visual field, the observer has to resist this distraction in order to focus his/her attention on the relevant information.

Our study was designed to investigate whether attentional control, in particular the ability to resist interference from distractors, occurring in the visual field, is affected in children with BECTS. To address this question, a variant of the additional singleton paradigm, initially described by Theeuwes (1994), was used. In this paradigm, a distractor (a singleton) appearing in the display, automatically captures attention, although it is irrelevant to the task in hand. Attention is thought to be captured when performance is slowed down by this irrelevant distractor as compared to performance on trials with no distractors (see Simons, 2000, for review). In our study, motion onset was chosen as distractor because moving targets have a high salience in attracting attention in the peripheral field. Abrams and Christ (2003) showed that motion automatically captures attention. In their study, targets were most easily detected in objects that had recently started to move as compared with objects that were not moving or that had been moving continuously for some time.

If epilepsy impairs attentional control, children with BECTS would be expected to exhibit a poorer capacity to resist interference from distractors and would therefore exhibit a greater magnitude of attentional capture. The presence of a distractor in the visual field might cause a more important attentional cost in children with idiopathic epilepsy than in healthy, control children. This hypothesis was formulated on the basis of results observed in children with focal idiopathic epilepsy, particularly BECTS (Weglage *et al.* 1997, Croona *et al.* 1999, Chevalier *et al.* 2000). A second objective of our study was to determine whether this deficit is specific to BECTS or if it can be also observed in children with IGE since these latter also present attentional deficits on standardized tests.

Methods and subjects

Children with epilepsy

Thirty-six children with idiopathic epilepsy, aged 7-12 years ($m = 9.4$; $SD = 1.6$; 23 boys and 13 girls) participated in this study: 18 patients with benign epilepsy with centrotemporal spikes (BECTS; 13 boys and five girls) and 18 patients with idiopathic generalized epilepsy (IGE; ten boys and eight girls), comprising 11 patients with generalized tonic-clonic seizures only and seven patients with both tonic-clonic seizures and absences. They all attended regular classes. The parents of each participant signed an informed consent form after the study had been explained to them. The study was approved by the local ethics committee.

The diagnosis of BECTS or IGE according to the ILAE classification, based on clinical history and recent EEG recordings, was confirmed in a pediatric neurology unit. EEG demonstrated centrotemporal biphasic spikes in patients with BECTS and generalized spikes-waves in children with IGE. To be included in this study, children with epilepsy had to have a normal neurological and neuroradiological examination.

Exclusion criteria were as follows: concomitant neurological or psychiatric disorders, sensorimotor deficits, neurosurgery, neurological medication other than antiepileptic treatment, combination therapy (two or more antiepileptic drugs) and/or Full Scale IQ (FSIQ) estimate ≤ 70.

None of the children had frequent seizures. Thirty children had not experienced a seizure for at least six months and only eight children had had a seizure in the last six months preceding neuropsychological evaluation. In the subgroup with generalized epilepsy, seven children also had absences but, at the time of the study, their epilepsy was controlled, none of them had had absences in the six months prior to evaluation and EEG failed to demonstrate any electroclinical seizures or epileptic discharges.

Interictal EEGs were performed either the same day or the previous or following days of the experimental study. These EEGs were normal in children with IGE, and in 10 of 18 children with BECTS. Only a few rolandic spikes were observed on the EEG in eight patients. Nocturnal EEG was performed in 16 children (seven children with IGE epilepsy and nine with BECTS). None of the nocturnal EEG showed frequent EEG discharges. In the IGE group, three nocturnal EEGs were normal and four demonstrated a few generalized spikes or spike-waves during sleep. In the BECTS group, nocturnal EEGs were normal in three cases and, in six other children, showed only occasional spikes without exacerbation during sleep.

All children received single-agent therapy with the usual antiepileptic medications for idiopathic epilepsy. The clinical and electroclinical characteristics for the two groups are summarized in *table 1*.

Healthy control children

Eighteen healthy children were selected to constitute a control group matched for age and gender (13 boys and 5 girls), aged 7-12 years ($m = 9.02$; $SD = 1.3$). These children all attended regular classes and presented normal academic achievement. Exclusion criteria were as follows: history of neurological or psychiatric disorders, sensorimotor deficits and/or learning difficulties.

Demographic and clinical variables were submitted to separate analyses of variance (ANOVA) to determine whether the groups were adequately matched. Age-at-onset of seizures, duration of epilepsy and FSIQ were not significantly different between the BECTS and IGE groups. Age-at-testing was not significantly different between the three groups (BECTS, IGE and controls).

Materials and procedures

Children with epilepsy were evaluated individually in one session. Their intellectual capacities were assessed with a French version of the Wechsler Intelligence Scale for Children – Third Edition (WISC-III).

In order to assess attentional control, particularly the ability to resist interference from distractors, children with epilepsy were tested in an attentional capture paradigm. The task was implemented on a PC laptop computer connected to a 17-inch colour screen and lasted about 4 minutes. The paradigm was as follows: a target (a black square subtending 3° of visual angle) appeared randomly 4° above or below a central fixation cross. It remained on the screen until response or for 1500 ms. The task was to locate the square by pressing a response key corresponding to the spatial location of the target on a vertical box containing two keys. Two distractors (red disks) appeared simultaneously with the fixation cross and remained on the screen. They were centered 4° to the left and right of fixation and subtended 3° of visual angle at a viewing distance of 40 cm. An example of the paradigm is shown in *figure 1*.

Performance was compared under two conditions: (1) under baseline conditions, the two distractors remained stationary and (2) under attentional capture conditions, one of the distractors moved suddenly [for 35 ms with a left/right or right/left translation of 30 pixels (about 0.5°)]. The two conditions were randomly and equally represented. Participants were asked to ignore the distractors and to only pay attention to the spatial location of the square. Under attentional capture conditions, the left or the right distractor moved with an equal probability. There were 100 trials (50 with stationary distractors, 25 with movement of the left distractor and 25 with movement of the right distractor). Response times (RTs) and accuracy were recorded.

Healthy control children only performed the attentional capture task. In order to test children with epilepsy and healthy control children under similar conditions, children with epilepsy performed this task first.

Data analysis

Data analysis was performed with STATISTICA 6.1. software.

For the attentional capture paradigm, response times (RT) above or below 2 *SD* of the group mean RT were excluded from the analysis for each participant in each condition. This procedure resulted in an overall exclusion of 1.4% of the data in the control group, 2.8% in the IGE group and 3.1% in the BECTS group. Only RTs for correct responses were taken into account in the analysis. Statistical analysis (ANOVA) was performed on mean RTs, number of errors (inaccurate location responses) and number of omissions (no response within the time allowed) with group (BECTS *versus* IGE *versus* controls) as the between-subjects factor and condition (control condition: trials with stationary distractor *versus* attentional capture condition: trials with moving distractor) as the within-subjects factor. *Post-hoc* group differences were computed using the Newmans-Keuls statistic. Throughout the present study, an alpha level of 0.01 was used for all comparisons.

Results

The results of the attentional capture paradigm are presented in *table 2*.

A statistically significant group effect was observed for the RTs ($f\,(2, 51)=1231$, $p < 0.00004$) and for the number of omissions ($f\,(2, 51)=4.58$, $p < 0.01$). Children with IGE or BECTS were significantly slower (respectively, $p < 0.0003$ and $p < 0.0003$) and made significantly more omissions (respectively, $p < 0.04$ and $p < 0.01$) than controls. IGE and BECTS groups were not significantly different as regards the RTs ($p = 0.20$) and the number of omissions ($p = 0.35$). There was no significant difference between the three groups regarding the number of errors ($f\,(2, 51)=0.25$, $p = 0.60$).

Table 1. Clinical characteristics and results of WISC-III in the population
(IGE: Idiopathic Generalised Epilepsy; BECTS: Benign Epilepsy with Centro-Temporal Spikes).

Patients	Gender	Age°	Age° at seizures onset	EEG	Nocturnal EEG	AED	FSIQ[a]
IGE group							
1	F	9y 9m	7y 5m	Normal	No	VPA	74
2	M	7y 1m	5y	Normal	No	VPA	74
3	F	9y	6y 3m	Normal	Abnormal	VPA	85
4	F	11y 9m	11y 7m	Normal	No	VPA	83
5	M	9y 7m	6y	Normal	No	VPA	86
6	M	11y 10m	9y	Normal	Abnormal	OXC	88
7	M	11y 5m	5y	Normal	No	VPA	89
8	M	11y 7m	7y	Normal	Normal	OXC	79
9	F	11y 7m	4y 8m	Normal	No	VPA	74
10	M	7y 7m	4y 6m	Normal	No	VPA	98
11	M	10y	8y	Normal	Normal	VPA	79
12	M	8y 7m	7y 1m	Normal	Normal	VPA	79
13	M	10y 1m	8y 8m	Normal	No	OXC	83
14	F	8y 9m	8y 2m	Normal	Abnormal	VPA	78
15	F	8y 7m	7y 5m	Normal	No	VPA	95
16	F	7y 2m	4y 11m	Normal	No	VPA	110
17	M	11y 9m	11y 3m	Normal	Abnormal	VPA	105
18	F	7y 1m	6y	Normal	No	VPA	85
Mean		*9,6*	*7,1*				*85,7*
SD		*1,7*	*2,1*				*10,4*
BECTS group							
19	F	7y 9m	6y	Normal	No	VPA	71
20	M	7y 7m	7y	Normal	No	VPA	122
21	M	10y 6m	6y 4m	Normal	Normal	OXC	71
22	M	7y 2m	6y 9m	Normal	No	OXC	75
23	M	11y 5m	5y	Normal	Normal	OXC	79
24	M	10y 8m	10y 3m	Spikes	Abnormal	VPA	86
25	F	11y 9m	8y 2m	Normal	No	VPA	95
26	M	7y 4m	6y 8m	Normal	No	VPA	108
27	M	8y 7m	6y 9m	Spikes	Normal	VPA	90
28	F	8y 3m	3y 5m	Normal	No	OXC	81
29	M	9y 2m	6y 8m	Spikes	No	VPA	108
30	F	9y 4m	3y	Spikes	Abnormal	VPA	75
31	F	7y 6m	6y 6m	Normal	Abnormal	VPA	91
32	M	9y 5m	7y 6m	Spikes	Abnormal	VPA	103
33	M	7y 7m	5y 11m	Normal	Abnormal	VPA	98
34	M	9y 7m	9y 5m	Spikes	No	VPA	90
35	M	8y 5m	7y 4m	Spikes	No	VPA	113
36	M	9y 9m	8y 11m	Spikes	Abnormal	VPA	113
Mean		*9,0*	*6,7*				*92,7*
SD		*1,4*	*1,8*				*15,8*

F: Female; **M**: Male; °: in years; months; **VPA**: Sodium valproate; **OXC**: Oxcarbazepine.
[a] m=100 and SD=15; **FSIQ**: Full Scale IQ estimate; y: year; m: month.

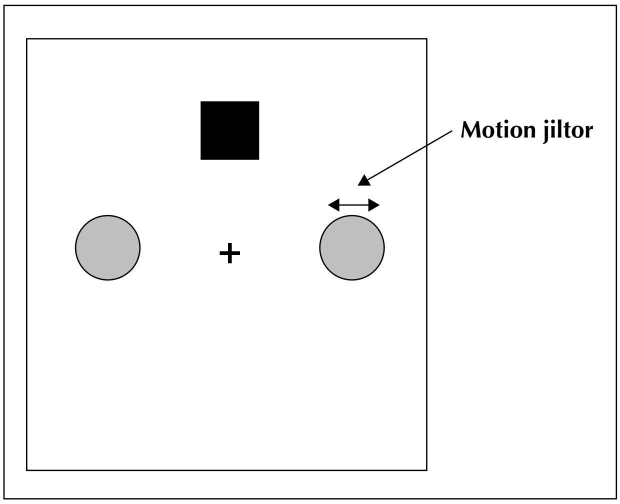

Figure 1. Example of the stimulus display when the target appears above fixation.

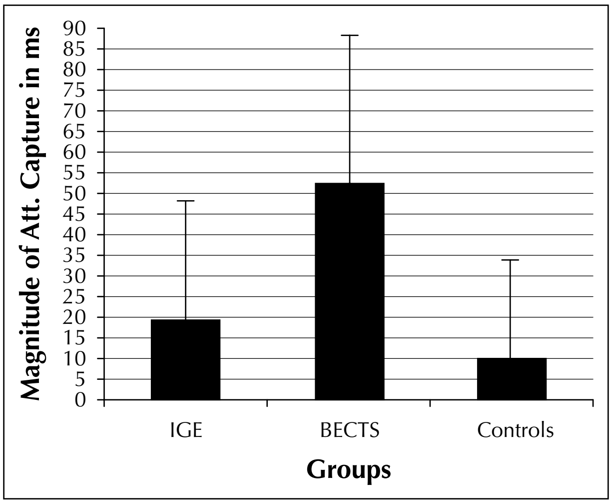

Figure 2. Magnitude of attentional capture in ms (RTs for trials with moving distractors minus RTs for trials with stationary distractors) as a function of the group of participants.

A statistically significant attentional capture effect was observed for RTs, but not for the number of errors or omissions. In the three groups, RTs were significantly longer when a distractor moved in the visual field than in trials in which the distractor remained stationary (f (1, 51)=43.09, $p < 0.0000001$). The interaction between group and condition was statistically significant only for RTs (f (2, 51)=9.92, $p < 0.0002$, *figure 2*). The magnitude of attentional capture, measured by subtracting RTs for trials with moving distractors from RTs for trials with stationary distractors, was significantly greater for children with BECTS (m = 52 ms, SD = 36) than for children with IGE (m = 19 ms, SD = 29; $p < 0.002$) and than for controls (m = 10, SD = 24; $p<0.0004$). The attentional capture effect on RTs was not significantly different between the IGE group and controls ($p = 0.78$).

Discussion

The attentional capture paradigm used in our study was designed to investigate the ability to resist interference

Table 2. Performance (means and standard deviations) of the three groups in the attentional capture task.

	IGE (*n*=18)	BECTS (*n*=18)	Controls (*n*=18)
RTs with stationary distractor (in ms)	605	646	458
	(133)	(127)	(122)
RTs with moving distractor (in ms)	624	699	468
	(142)	(146)	(119)
Errors with stationary distractor	1.8	3.6	3.3
	(1.6)	(2.9)	(2.5)
Errors with moving distractor	1.6	4.1	3.2
	(1.8)	(4.2)	(2.5)
Omissions with stationary distractor	0.9	2.1	0.1
	(1.9)	(4.2)	(0.3)
	(1.5)	(3.6)	(0.3)
Omissions with moving distractor	1.1	3.1	0.3
	(1.4)	(4.4)	(0.7)

from distractors that automatically capture attention, in children with idiopathic epilepsy.

Children with epilepsy presented significantly longer mean RTs than controls, regardless of the type of epilepsy. However, the number of errors was not significantly different between the three groups. The number of omissions was also significantly greater in children with epilepsy than in controls, regardless of the type of epilepsy. This result could be secondary to attention deficit but also to slower responses. All studies concerning the neuropsychological profile of children with epilepsy (idiopathic or other) have reported a general slowness, contributing to poorer performance on timed tasks (Black and Hynd 1995, De Saint-Martin *et al.* 2001, Culhane-Shelburne *et al.* 2002, Singhi *et al.* 1992). This suggests that epilepsy *per se,* and/or its treatment, has a deleterious effect on the motor speed and/or on the speed of information processing.

Children with epilepsy, like the controls, displayed a significant attentional capture effect characterized by longer RTs in the presence of a moving distractor. However, this effect appeared to differ according to the type of epilepsy, as the magnitude of interference from moving distractors was significantly greater in children with BECTS than in children with IGE and controls. This result suggests that children with BECTS are more susceptible to distractors occurring in their visual field.

Children with BECTS have normal, but nevertheless low IQ compared to controls considered to have normal IQ. However, IQ does not seem to interfere with resistance to distractors, as the results obtained in children with IGE, who also had a lower IQ, were similar to those observed in controls. Our data support the hypothesis of less efficient attentional control in children with BECTS. This hypothesis have been previously proposed by Chevalier *et al.* (2000) and Gündüz *et al.* (1999), who reported response inhibition difficulties in BECTS. However, these two studies did not compare BECTS *versus* other epilepsy syndromes. In our study, the comparison between IGE and BECTS suggests that less efficient attentional control could be a specific feature of BECTS. The underlying mechanisms of attentional difficulties in children with epilepsy appear to be different according to the type of epilepsy syndrome.

Attentional control is still in the process of development during the period of onset of idiopathic epilepsy. Experimental and clinical evidence emphasizes the contribution of prefrontal areas in the mediation of attentional control (Posner and Rothbart 1991). These findings suggest that damage to the connectivity of frontal lobes with other cerebral areas caused by epileptiform discharges may affect the development of attentional control in BECTS (Chevalier *et al.* 2000; Croona *et al.* 1999, Weglage *et al.* 1997).

A positive correlation between the frequency of epileptiform discharges on EEG recording, and performance in attentional and executive tests has been reported in children with focal idiopathic epilepsy (D'Alessandro *et al.* 1990, Metz-Lutz *et al.* 1999, Tromp *et al.* 2003). Moreover, attention deficits in children with epilepsy are often considered to be the result of an epileptic encephalopathy due to frequent discharges during sleep (Sanchez-Carpintero & Neville, 2003). Some authors also hypothesized that attention difficulties reflect poor alertness secondary to sleep fragmentation (Kohrman and Carney 2000). We chose to perform this study in children whose epilepsy was controlled, with no seizures during the previous weeks, in order to minimize the effect of seizures. Even if a concomitant EEG was not performed during the computerized paradigm, interictal EEGs were normal or demonstrated only few epileptic discharges during the previous or following days. These findings suggest that the deficit of attentional control observed in children with BECTS may not be due only to the frequency of seizures and EEG discharges. Attention deficit and specifically sensitivity to distractors in children with BECTS could also result from the occurrence of epilepsy during the development of attentional control.

Concluding remarks

The longer reaction time observed during a computerized task in children with BECTS and with IGE, suggests the existence of a slowness of perceptual, motor or information processing in both groups. Children with BECTS exhibit a specific neuropsychological profile. They seem to have an inability to inhibit distractors, which may contribute to less efficient attentional control. These results confirm the value of using experimental tasks to better understand the cognitive processing involved in learning difficulties, and to differentiate between populations of children with epilepsy as regards attentional and executive measures. □

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